Analysis of Hyperspectral Image Data for the CoBOP Experiments

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LONG-TERM GOALS

Our long-term goal is the development of spectral analysis tools that fully exploit the information content in hyperspectral image data, particularly as it applies to remote sensing of ocean color.

OBJECTIVES

Our objectives are to develop specific algorithms and procedures to classify water types, differentiate among different bottom types and extract bathymetry from passive hyperspectral image data. When the water type and bottom reflectance are uniform over the study area, bathymetric mapping with passive remote sensing data is a relatively straightforward, one-variable problem and requires a minimum of field data. It is even possible to extract a relative water attenuation coefficient from spectral image data. The problem quickly becomes much more complex when the water type and bottom type vary over the scene. In that case, the depth cannot be determined without simultaneously resolving the bottom reflectance and basic optical water properties. Bathymetric mapping is thus an inherently multivariate problem requiring at least several spectral bands. We expect that effective use of hyperspectral image data will lead to significant improvements in the accuracy and detail of the results.

APPROACH

Our approach has several components.

1) Component one has been to develop methods for identifying spectral features independent of any classification or modeling process.
2) A second component involves radiative transfer modeling using the full radiative transfer code provided by HYDROLIGHT (Mobley, 1994). In this task, we have focused on building a spectral library of inherent optical properties (IOP's) for each component of the water (pigments, dissolved organics, particulates, etc.). These were used as input to HYDROLIGHT to predict the spectral water-leaving radiance given a specified vertical distribution for each component. This will provide a tool for evaluating the sensitivity of the water-leaving radiance to changes in the IOP's and their distribution in the water column as well as to determine changes in illumination. The predicted water-leaving radiance may also be matched to measured water-leaving radiance.

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3) A third component involves inverting a simple two-flow radiative transfer model (Philpot, 1987; Philpot, 1989). While the simple model may not be able to characterize the full range of in-water optical properties, we expect it to be an adequate representation for remote sensing applications in many, if not most, situations.
4) We are also developing a spatial-spectral image segmentation algorithm to discriminate among regions with different bottom types. This procedure is independent of the derivative analysis. The idea is to identify regions in the hyperspectral image data that are spectrally similar in the sense that the water attenuation and bottom type are uniform within a segment.

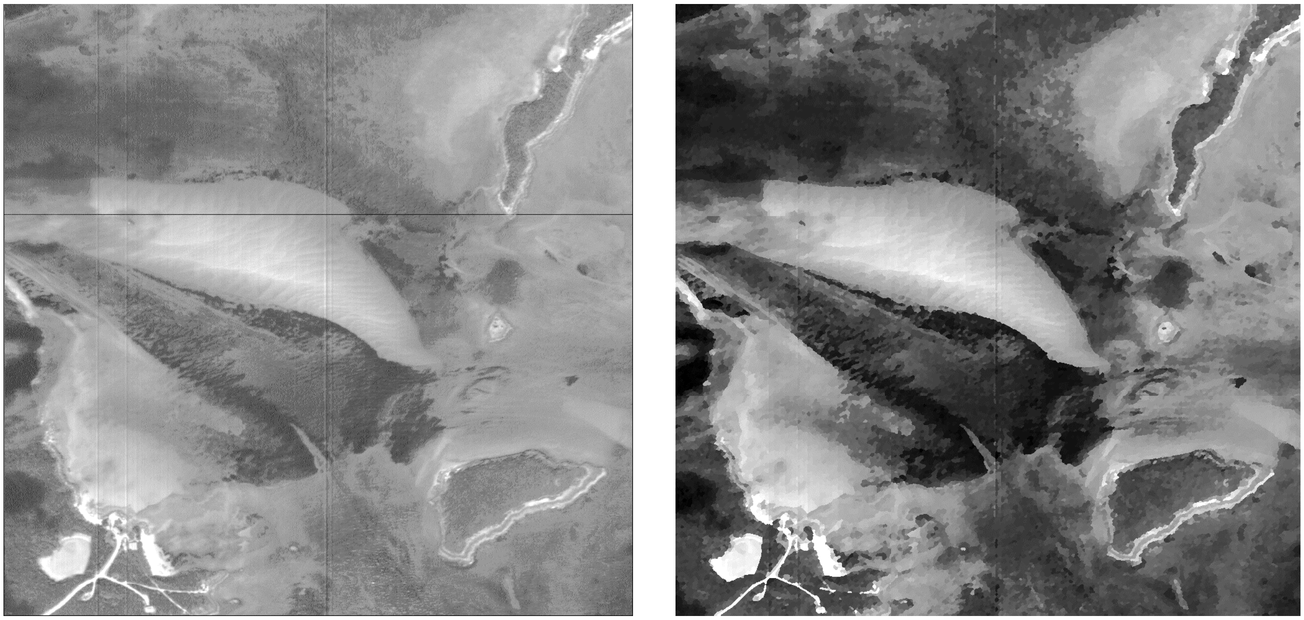
WORK COMPLETED

1) A software package, HYPERSPEC, designed to facilitate the computation of spectral derivatives has been completed and distributed to interested PI's.
2) A second software package, Ocean Optics Plankton Simulator (OOPS) has been developed and made available to interested PI's. This is a visual, interactive tool to facilitate the investigation of the effect of changes in IOP's and their vertical distribution in the water column on the water-leaving radiance.
3) Another program was developed to process data acquired by the Hyperspectral Tethered Spectroradiometer Buoy (HTSRB, Satlantic, Inc.) This program is used to apply the spectral and dark current corrections for the spectral data. It can also be used to remove faulty data and to apply several other application-dependent corrections.
4) A procedure to extract an apparent water attenuation and bottom radiance term from measured water-leaving radiance has been developed and prototyped using HYDROLIGHT and TSRB data.
5) A preliminary image segmentation program has been written.

RESULTS

Inversion of the two-flow model to extract information about the bottom type, bottom depth, and water quality requires some independent information. The task will be significantly easier if the inversion can be applied to data that is limited to only one bottom type. The image segmentation procedure is designed to do this. It has been applied to a PHILLS image of the Adderly Cut study site at Lee Stocking Island, Bahamas (Figure 1a, b). The process appears to have been successful, but it has yet to be verified in detail.

Within the regions of constant bottom type and water type to be identified by the image segmentation procedure, it should be possible to characterize the effective two-way attenuation of the water, $g(\lambda)$, by performing a principal component analysis on linearized hyperspectral data. Alternatively, given the measured remote radiance for two known distinct depths and assuming a reasonable value for the deep water radiance, it is possible to solve for both the effective two-way attenuation, $g(\lambda)$, and $L_b(\lambda)$, the radiance term representing the contrast between bottom and water reflectance. (At $z = 0$, $L_b(\lambda)$ is the radiance from the bottom alone.) Preliminary tests of the extraction procedure have been applied to synthetic data (created with HYDROLIGHT runs) and from field data collected using the TSRB. In both cases, the extraction procedure was very effective (Figure 2a, b).



a) Original image   b) Segmented image

Figure 1: Illustration of the initial spatial spectral image segmentation procedure results.

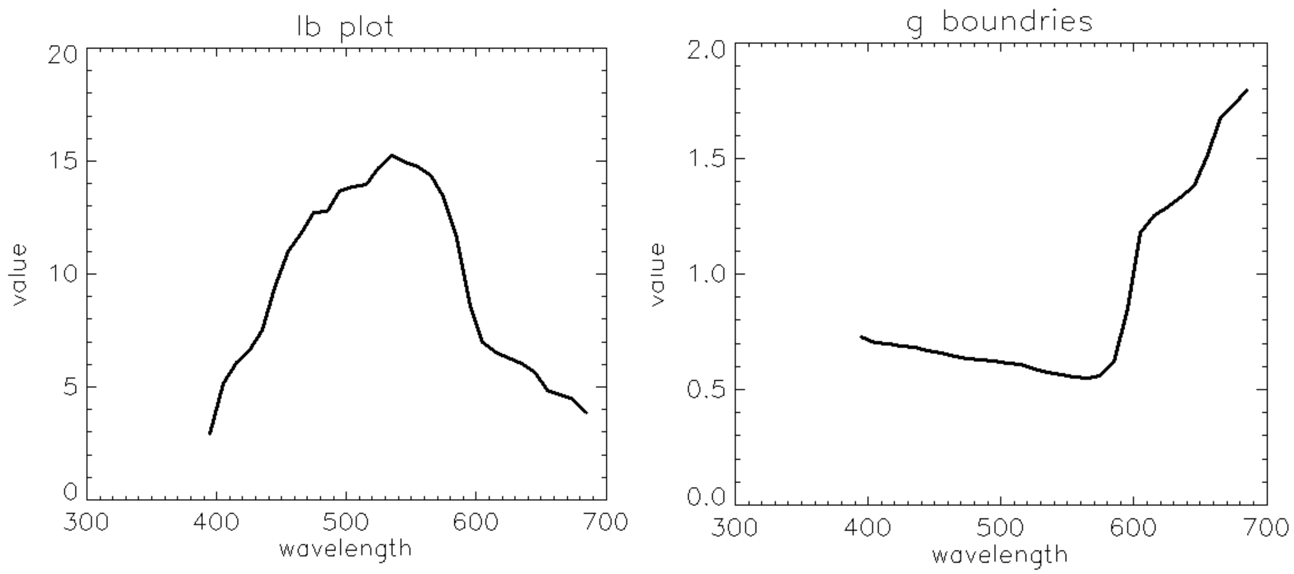


Figure 2: $L_b(\lambda)$ and $g(\lambda)$ derived from HTSRB data over the ooid shoals site at Lee Stocking Island, BA. For this test, over shallow waters, the deep water radiance, $Lw(\lambda)$ was taken to be zero.

IMPACT/APPLICATIONS

We have taken an approach to analyzing hyperspectral data that combines radiative transfer modeling, identification of unique spectral features, and spatial-spectral pattern recognition for segmenting an image. The goal is to extract depth, discriminate among bottom types, and characterize the water quality. This procedure has the potential to be much more robust and more effective than existing procedures for bathymetric mapping.

TRANSITIONS

1. Our program for the processing of the HTSRB data has been used by other PI's in ONR's CoBOP program and it is being incorporated into the next version of software by Satlantic.
2. The software for computing spectral derivatives has been provided to other PI's in CoBOP who are using derivatives in their data analysis.
3. The OOPS software has been made available to other investigators in the HyCODE and CoBOP programs.

RELATED PROJECTS

None

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PUBLICATIONS

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